

Introduction

The spatial resolution of various instruments and missions is a very important thing for us to consider in the course of our work. We're using data that come from several different surveys, with different spatial resolution. This is most vividly seen by a comparison of WISE channel 1 and 2 with Spitzer IRAC channel 1 and 2 because the wavelengths are very nearly the same (and the telescopes are different), but it will matter a lot in particular for the WISE, AKARI, PACS, & MSX data.

MY BROAD GOALS for you in doing this are to (1) develop a sense of what spatial resolution means and how it changes between telescopes, e.g., WISE vs. Spitzer vs. 2MASS vs. Herschel resolution; and (2) understand what the challenges will be for us in matching across wavelengths.

Ancillary goals (e.g., you can't do this worksheet without also accomplishing these): (1) get used to working with FITS files, manipulating stretches, etc.; (2) identifying objects in and measuring distances on FITS files; (3) learn how to use Finder Chart (and other IRSA tools), ds9, and Skyview as resources to be used down the road on whatever you find yourself doing next.

OUR SCIENCE GOALS for this portion of work (after you've mastered skills from above) include defining what region should we use to encompass the Nebulous Stream. Our ancillary science goals (based on a question one of you asked) is to measure the distance between clumps in the NS.

For a general introduction, please start with the main text already on the wiki for [Resolution](#). Please also look at the examples lower on that page, but you don't need to actually do the one that suggests that you go download data, etc. The skills you might have gained from that specific example will be stuff that we do as part of our project.

We will be using IRSA's [Finder Chart](#) and [IRSA Viewer](#) (which is a more generic version, accessing more data at IRSA) to retrieve images, but for some surveys, you could also use [Goddard's Skyview](#) to retrieve FITS images. You need a way to view and interact with FITS files (see FITS explanation below). Finder Chart (and IRSA Viewer) allow you to interact directly with the FITS files. You could also use ds9, which you can download here: [DS9](#). Also, ds9 was the topic of a tutorial in [NITARP tutorials](#).

Basics and other things to note

Background information

If you need a refresher on mosaics, see [What is a mosaic and why should I care?](#)

If you need a refresher on angular measures on the sky, see [this site from LCOGT](#).

A bit more information on [FITS format](#) is elsewhere on the wiki. The most important thing about FITS format vs. other image formats is that JPGs (and for that matter GIFs or PNGs) are "[lossy compressed](#)" files, which means that images in those formats actually LOSE INFORMATION, particularly in comparison to the FITS file. JPGs are just fine for images you take of your kids with digital cameras - you rarely ever see evidence of the loss of information. (As an aside - you might see evidence of it if you take a picture of something with high contrast, or a sharp edge somewhere in the image. If you look at the jpeg up close, you will see 'ringing' of the

sharp edge, which looks kind of like blurring. The Wikipedia page on lossy compression linked above has an example of loss of information with JPGs.)

So, what this means is: **any time you are doing science**, whether that is using your eye to see small details in the image, or measuring distances, or doing photometry, **you always want to be using the FITS file, never a JPG, PNG, or GIF.**

When you download the FITS files (from anywhere), the default filename is very likely related to the process id on the server, e.g., it won't mean anything to you 10 minutes after you download it. In the process of downloading images, you should rename the images straightaway to be something that you can understand and remember later on.

We will largely be using [Finder Chart](#), [IRSA Viewer](#), and [ds9](#). I'm including information for [Goddard's Skyview](#) for future reference. Detailed documentation for all of these is available at their respective websites. I've made videos for many of these tools, either in my feed or the [IRSA YouTube feed](#).

Skyview

For [Skyview](#), you should use the full Query form, not Quick View and not Non-Astronomer's page.

Skyview pulls together some huge number of surveys in one place and makes them accessible to you in an easy, fast interface. It will resample and regrid and remosaic all sorts of surveys for you, from gamma rays to the radio. (That is, as we will see, both a strength and a weakness.) I don't know exactly if it conserves flux (e.g., if one can still do photometry off of the mosaics it provides); I would err on the side of caution and NOT use this for anything other than morphology, e.g., do science by eye with the mosaics, and you can use them for distance measurements on the images, but don't do photometry on these mosaics.

Skyview will always spawn the same second window for the results. The first time you call it, it will spawn a second browser tab or window (depending on your local configuration), and then, if you don't close that second tab or window explicitly, the next search results will go into that same window, even if it's hidden below where you are currently working. *It will make it seem as if nothing has happened when you submit your search request.*

In Skyview, you can ask for more than one survey at the same time, but it uses the same 'common options' you specify on the query page. To select more than one survey that are not adjacent in the list, hold down the command key while clicking. (That is, at least, on a mac. Your mileage may vary.)

Skyview will allow you to download both the JPG and the FITS file (click on "FITS" to download it). You want FITS, as per above. :)

The four most important parameter choices Skyview gives you are:

- center position
- survey (wavelength)
- image size in pixels
- image size in degrees

Skyview will happily and without complaint or warning resample and regrid the pixels to whatever scale you want. What do you need to do to get 'native pixel' resolution out of Skyview? You should figure out how many pixels you need to cover your region, and the native pixel sizes, so go and do the math, and ask Skyview to

give you a full-sized image of your desired size. Note that you can request more than one survey at a time, but Skyview will use the same parameters for each of them

If, in the future, you need to find Skyview, you will probably need to google "Goddard Skyview" as there is at least one other software package called Skyview (including one at IPAC that is mentioned more than once in the wiki) that does something else entirely.

FITS Viewers: ds9

You need software capable of reading FITS files. There is some information on using a variety of packages [here](#).

As our first but certainly not last example of "astronomers using whatever software you are most familiar with to do the job", you are more than welcome to use your own favorite FITS viewer (if yours has an easy way to measure distances).

You might as well start to get comfortable with using [ds9](#). It's free, and available for just about any platform. There are at least 2 tutorials on using ds9 developed by NITARP students on the wiki for doing some specific things - search in the wiki on ds9 - and more from the rest of the web, including some listed at the bottom of [this page](#). Also, ds9 was the topic of a tutorial in [NITARP tutorials](#).

When clicking around on ds9 images, you may occasionally leave behind a green circle; this is a "region", and they are ultimately very helpful, but when learning things, they can be very annoying. To make accidental regions go away, pick the region, and hit backspace or delete on your keyboard or from the top regions menu.

For this worksheet, you need to be able to measure distances. Measuring distances in ds9 is basically creating a special 'region' that is a ruler, so you may find it clunky. From the menus on the top, select Region/Shape/Ruler. Click on one end of what you want to measure, then move to the other end and click again (or click-and-drag; you may need to experiment to see what your system wants). A line with arrows will be drawn connecting the two, along with the distance in text and dotted lines completing the triangle. By default, the distance will be in physical units (pixels of the image you are viewing), but by accessing the region's Get Information panel (top menu: Region/Get information; buttons in the middle of the ds9 screen: Region/Information), you can change both the endpoints and (more usefully) distance units to WCS so that the units will be in degrees, or minutes, or seconds.

In recent years, we have had some skittishness from Windows machines when running ds9. It may very well be that you will have an easier time using IRSA tools (see next) than ds9, although ds9 is (for the moment) ultimately more powerful.

ds9 Tutorials from Babar from 2012:

- [Video 1: How to load and view and image in ds9](#)
- [Video 2: How to read information about your image in the information panel of ds9](#)

ds9 Tutorials from the official NITARP tutorial (Jan 2013):

- [Part 1: ds9 overview](#) - what is ds9, etc (10.5 min)
- [Part 2: the first half of the ds9 demo](#) - getting it started, basics of usage (19 min)
- [Part 3: the second half of the ds9 demo](#) - more advanced tips and tricks (25 min)

Tutorial from Milton Johnson from 2016:

- [Starting ds9 from the command line in Windows](#) (10 min)

FITS Viewers: Finder Chart (and IRSA Viewer)

[Finder Chart](#) and [IRSA Viewer](#) both use software that is called "Firefly", and both tools have a similar look-and-feel. Finder Chart was originally designed to create finder charts for use at a telescope, but it has evolved into one of IRSA's most popular tools. It provides images from up to 5 surveys in up to 21 bands, and allows simultaneous searches of the corresponding catalogs. IRSA Viewer is a more generic version of Finder Chart, providing the FITS viewer and one-by-one image retrieval and catalog searches.

In both cases, the search capability is integrated with the FITS viewer capability. (In Skyview, these capabilities are not integrated.) When Finder Chart or IRSA Viewer give you images as a result of a search, you are looking at (and interacting with) the original FITS files. There is a toolbox on the top of both tools that can be used with the images. You can change color stretches and color tables, you can leave markers on the image, you can read in catalogs (and ds9 regions files), etc. In Finder Chart, by default, all the images are locked together, so what you do to one image (zoom, etc.), happens to all of them. (To unlock them, click on the lock icon in the image toolbox.) (Just for completeness, in IRSA Viewer, there is no *a priori* guarantee that the images that are loaded are of the same patch of sky, so they are by default NOT locked.)

You can also measure distances in Finder Chart (or IRSA Viewer). For this Resolution worksheet, you need to be able to measure distances. Click on the ruler icon, then click and drag in the image to measure a distance. Click on the layers icon to bring up a pop-up that specifies the units for the length of the vector you have drawn in degrees, arcminutes, or arcseconds.

Images retrieved via Finder Chart or IRSA Viewer are coming from the original archives corresponding to each survey, so they are basically guaranteed to be unresampled images, so they are OK for doing detailed science, including photometry. There is an excruciatingly simple way of guesstimating photometry within Finder Chart or IRSA Viewer, but it's nowhere near accurate enough for scientific analysis.

Finder Chart and IRSA Viewer also let you retrieve and overlay catalogs. Skyview doesn't let you do that at all. On the other hand, Finder Chart and IRSA Viewer are limited to the tiles currently publicly stored here at IRSA; most of the time, you won't notice the tiles, but the 2MASS tiles are crazy small (that's a technical term) so if you ask for any reasonable amount of sky at all, you'll get a tiny 2MASS image surrounded by black, blank sky. In order to get big 2MASS images, you need to get them some other way, like from Skyview.

Click on "prepare download" to get the FITS (or the pngs, or a pdf, or the html for that matter).

The [IRSA YouTube Feed](#) has playlists on both Finder Chart and IRSA Viewer.

Notes on Distances

You can also measure distances by hand by comparing pixel coordinates. Note that as you move your mouse around on the image in any of these FITS viewers, it will give you an updated readout of the RA and Dec near the top. You can change this from hh:mm:ss ddd:mm:ss format to decimal degrees for both RA and Dec -- for ds9, you do this by picking from the "wcs" menu at the top, either 'degrees' or 'sexagesimal'. Make a note of the RA/Dec from which you want to measure a distance, and the RA/Dec of the end point of the distance measure.

No matter how, exactly, you do this, **WATCH YOUR UNITS. RA by default is in hours, not degrees. Dec by default IS in degrees.** How do you convert between hours and degrees? (Hint: there are 24 hours of RA ...and 360 degrees.)

Technically, to be absolutely correct, because you are calculating distances on a sphere, in order to do this, you need to do spherical trigonometry. This matters because the angle subtended by 1 hour of RA on the celestial equator is much larger than that subtended by 1 hour of RA near the celestial pole. For quick and dirty purposes, it should be mostly fine to simply subtract the RA and Dec to get a reasonable estimate of the distance BUT WATCH YOUR UNITS because RA by default is in hours:min of time:sec of time, not deg:arcmin:arcsec.

The spherical trig does make a difference, though. See [this excerpt from someone's class notes](#) with some really nice graphics and explanations of why you need to do this, and how to do it right. (hint: For the distances we'll consider here, you need a cosine of the declination. I won't make you do the full spherical trig in most cases.) For the ambitious, anticipating skills you'll need downstream from this worksheet, try programming a spreadsheet to do this for you, given two RA/Dec position pairs. **NB: Be sure to watch your units on the Dec-- some cosine functions want radians, and some take degrees.** (Bonus: how much of a difference in IC417 does it make if you leave out the $\cos(\text{dec})$ term? Is that going to get worse or better if we move closer to the north celestial pole?)

Key takeaway points:

- [Finder Chart](#) gives you images from POSS, 2MASS, WISE, Spitzer (SEIP), AKARI, and IRAS in native pixel resolution (e.g., the pixels are the original ones from the data product from that survey). But it is limited by the size of the tiles provided by the corresponding survey.
- [IRSA Viewer](#) gives you images from many, many surveys at IRSA (and some not at IRSA), but it too is limited by the size of the tiles provided by the corresponding survey. Note that it can access the 6 degree 2MASS tiles.
- For some surveys, you can use [Skyview](#) to get a larger image. BUT you have to specify some parameters that you don't have to specify in Finder Chart or IRSA Viewer.
- Both ds9 and the IRSA tools allow you to overlay things. IRSA tools prefer IPAC table files (*.tbl files), but will accept regions files (*.reg); ds9 prefers regions files and doesn't know what to do with tbl files. Both regions and table files have unusual filename extensions, which makes Bob's email gag, and may make your computer complain too. They are both plain text files.
- The skills you're going to need here include: finding data, loading and viewing FITS images, aligning the images so that they all cover the same region of the sky, overlaying regions, changing the color stretch and maybe the color table. Also: moving back and forth between tools to find the capability you need.
- The reason I want you to pull the data from IRSA (or Skyview) directly and not just grab copies off Google or my Box drive is so that you know how to find data after your work on this team is done.

Suggestions for comparing resolution qualitatively between surveys.

Create a three-color image using bands of your choice. IRSA Viewer is the best way to do this using IRSA tools. On the main screen where you search for objects, you have a 3-color option, including loading from disk (as opposed to, say, IRSA holdings). However, the final resolution of the 3-color image is set by whatever you load into the red plane, so even though your lowest spatial resolution observations are probably also the reddest, in this context, don't load them into the red plane. ds9 also allows you to make 3-color images. For ds9, you need to tell it, "Ok, I want to make a 3-color image now" (Frame/rgb) and then you can load in each plane separately (in the pop-up, pick the color plane, then do File/open. Change the color plane and go back to file/open, etc.). Regardless of tool, whichever image has the lowest spatial resolution should be super obvious, because, say, the sources will

appear to have blue blobby rings if you load the lowest resolution image into the blue plane.

Align or align & blink images. You can flip through images in any of these tools; ds9 will do it for you if you want. For ds9, do file/open and find the first image; do frame/new then file/open and load the second image, etc. If you used the command line trick (ds9 *.fits), you will load all the images into individual tiles, in alphabetical order (which is most likely not wavelength order!). If you did them one-by-one, you will have them virtually in a stack, in the order you loaded them. To see all of them at once, click on 'frame' then 'tile.' To get it back to one at a time (in a virtual stack), pick 'single.' To line them up on the sky, pick from the top "frame" menu/match/frame/wcs to match them in terms of area on the sky. (That command means, "align all the images I have loaded in ds9 to be North up, all on the same spatial scale as the image I have selected when I initiate this command." WCS stands for world coordinate system, meaning that there is information about the ra, dec, and mapping of pixels to ra and dec in the FITS header.) To scroll through the whole stack, pick 'next' or 'previous', or go ahead and blink them. You can configure the length of time spent on each frame. You can change the ordering - explore the menu options on the top "Frame" menu. In the 'single' frame case, the image you are looking at is the active one; in the 'tile' view, the one with the blue outline is the active one. Click on the tile to make it the active one. The commands are similar in the IRSA tools; there is a "match WCS" tickbox and you can view images one at a time or tiled in the tool.